The recreational value of coral reefs: A meta-analysis

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Abstract

Coral reefs are highly productive ecosystems that provide a variety of valuable goods and services, including recreational opportunities. The open-access nature and public good characteristics of coral reefs often result in them being undervalued in decision making related to their use and conservation. In response to this, there now exists a substantial economic valuation literature on coral reefs. For the purposes of conducting a meta-analysis of this literature, we collected 166 coral reef valuation studies, 52 of which provided sufficient information for a statistical meta-analysis, yielding 100 separate value observations in total. Focusing on recreational values, we use US$ per visit as the dependent variable in our meta-analysis. The meta-regression results reveal a number of important factors in explaining variation in coral reef recreational values, notably the area of dive sites and the number of visitors. Different valuation methods are shown to produce widely different values, with the contingent valuation method producing significantly lower value estimates. Using a multi-level modelling approach we also control for authorship effects, which proves to be highly significant in explaining variation in value estimates. We assess the prospects for using this analysis for out-of-sample value transfer, and find average transfer errors of 186%. We conclude that there is a need for further high-quality valuation research on coral reefs.

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1. Introduction

Coral reefs are highly productive ecosystems that provide a variety of valuable goods and services to humans. These goods and services include recreational opportunities for diving, snorkelling and viewing (direct use values); coastal protection and habitat/nursery functions for commercial and recreational fisheries (indirect use values); and the welfare associated with the existence of diverse natural ecosystems (preservation values). Despite the provision of multiple valuable services, coral reefs face a number of anthropogenic threats, including destructive and non-sustainable fishing practices; sedimentation; pollution and waste; mining and dredging; non-sustainable tourism practices; and climate change related increases in temperature and sea-level (Cesar 2000). The optimal use of coral reef resources is distorted by the fact that reefs are often open access in nature and that many of the products and services provided by coral reefs have (quasi-)public good characteristics, i.e. they are characterised by a high degree of non-rivalry and non-excludability resulting in markets for coral reef services being absent or underdeveloped. This results in coral reefs being undervalued in decisions relating to their use and conservation. Partly in response to this situation, there is now a substantial literature on coral reef valuation.

This 'flood of numbers' necessitates the application of research synthesis techniques, and in particular meta-analysis, in order to assess the results of this literature as a whole and identify the key explanatory factors that determine coral reef value. Meta-analysis can be defined as a quantitative analysis of summary indicators reported in a series of similar empirical studies. Meta-analysis extends beyond a state of the art literature review by examining the results of multiple studies in a statistical manner. Proponents of meta-analysis maintain that the valuable aspects of narrative reviews can be preserved in meta-analysis, and are in fact extended with quantitative features (Rosenthal and DiMatteo 2001). Several meta-analyses have been conducted in the field of economic valuation of environmental resources, impacts, and services, for example for wetlands (Brander *et al*. 2006; Brouwer *et al.* 1999; Woodward and Wui 2000), woodland recreation (Bateman and Jones 2003), biodiversity (Nijkamp and Vindigni 2003), outdoor recreation (Rosenberger and Loomis 2000; Shrestha and Loomis 2001), and urban air pollution (Kaoru and Smith 1995). To our knowledge, this is the first meta-analysis of coral reef valuation results.

Due to the high costs and time required to perform primary valuation studies, there is substantial policy interest in using meta-analysis based value transfer functions to estimate values for unvalued 'policy sites' (Florax *et al*. 2002). The validity and accuracy of such value transfers has, however, been questioned (Brouwer 2000; Brouwer and Spaninks 1999; Downing and Ozuna 1996). We explicitly investigate the validity and robustness of value transfers based on this meta-analysis of coral reef recreational values.

The structure of this paper is as follows. Section 2 gives an overview of the empirical coral reef valuation literature. Section 3 provides a description of the recreational value data taken from this literature. We show the resulting descriptive statistics for coral reef values by region, recreational activity, and valuation methodology. Section 4 describes the setup for the meta-regression, presents the output, and provides an interpretation of the results. Section 5 discusses the potential and accuracy of using such a value function estimated through a meta-analysis for value transfer. Finally, Section 6 concludes and provides suggestions for future research and policy.

2. Overview of the coral reef valuation literature

With the exception of Moncur (1973), the literature on coral reef valuation did not start until the end of the 1980s with Hodgson and Dixon (1988), McAllister (1988) and Hondloe *et al.* (1987). These three papers interestingly did not estimate the total economic value of coral reefs, but rather the cost of coral reef degradation. Hodgson and Dixon (1988) also compared these costs of degradation (due to logging) with the benefits of a more sustainable management regime (logging ban). The early 1990s witnessed a slow expansion of the valuation literature with De Groot (1992), Dixon *et al.* (1993), Driml (1994), Leeworthy (1991), Pendleton (1995), Wright (1994) and a few others, as well as two more conceptual papers by Spurgeon (1992) and Barton (1994).

A rapid expansion in the number of coral reef valuation studies started a decade ago and now well over 100 studies have appeared on this issue. Cesar (2000) and Gustavson *et al.* (2000) both have monographs with collections of articles on coral reef valuation. Not a valuation study as such, the meta-analysis of dose-response functions of coral reef threats by Wielgus *et al.* (2002) is also an important publication in this field of research. Recent studies by Costanza *et al.* (1997) and Cesar *et al.* (2002) have estimated the value of coral reefs worldwide.

A number of these and other studies were used for the meta-analysis presented below. In total, 166 coral reef valuation studies were collected. Figure 1 presents a graphical representation of the distribution of these studies worldwide. Note that by far the most valuation studies have been carried out for the United States (Hawaii and Florida), Southeast Asia, and the Caribbean.

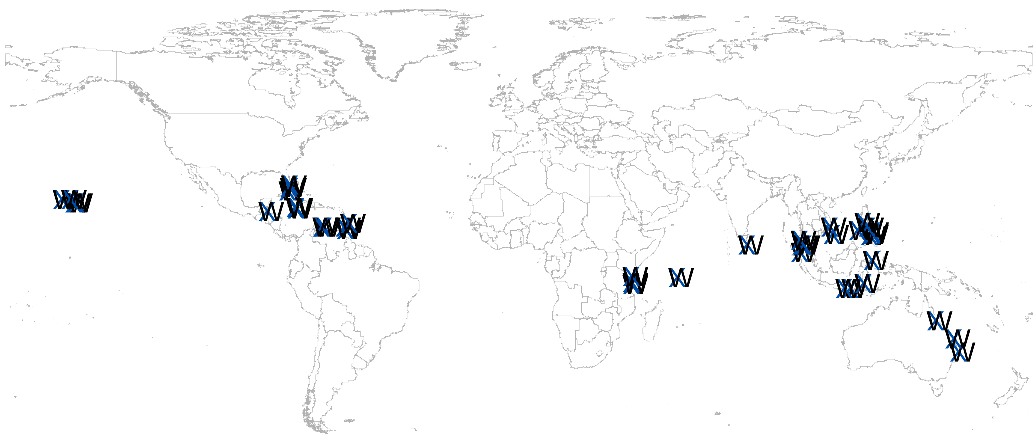

Figure 1. Location of valued coral reef sites

Valuation studies vary widely in terms of valuation techniques used, goods and services assessed and assumptions made. The choice of which coral reef services are valued is partly due to the site-specific significance of each particular service. Resource and budget constraints also mean that most valuation studies tend to select the most important goods and services for coral reef valuation. Additionally, the natural science basis for quantification of biotic and bio-geo-chemical services is often controversial. As a result, uncertain physical relationships are often also not quantified in monetary terms.

Although the valuation literature provides value estimates for almost all economic services provided by coral reefs, this study focuses on recreational values. The reasons for this restriction are to allow the definition of a standardised value in terms of visits, and to produce a data set with a manageable degree of heterogeneity. In addition, focusing on the recreational values of coral reefs allows the results of this study to address specific policy issues related to the management of coral reefs, such as the charging of user fees. Furthermore, recreation and tourism values are often the most important direct and indirect use values of coral reefs. Although not all tourism depends directly on coral reefs, much coastal tourism depends to an extent on the quality of the reefs.

3. Description of data

In order to compare value observations taken from the literature described above we require information on a number of key variables, including coral reef value, services being valued, location, year of valuation, and valuation method used. Of the 166 studies collected, 52 studies yielded sufficient information for a statistical meta-analysis on recreational values. From these 52 studies we were able to code 100 separate value observations, taking multiple observations from single studies. On average we obtain 2.17 observations per study, and a maximum of 15 observations from a single study (this study is Johns *et al*. 2001). Care was taken not to double count value estimates that are reported in more than one study, or to include estimates that were derived through value transfer. In addition to taking multiple observations from single studies, we also observe that some authors have produced multiple studies. This also raises concerns over the independence of individual observations, and we test for this in the meta-regression.

There is no standard reporting format for valuation results and consequentially value observations are reported in a wide variety of units (e.g. total values, per unit of area, per visitor etc.), for different time periods (e.g. per day, per visit, per year, NPV over a given time horizon etc.), and in different currencies and years of value. We therefore standardised these values to a common metric, which is US$ per visit in 2000 prices. Values from different years were converted to 2000 prices using GDP deflators from the World Bank World Development Indicators. PPP conversions were made to correct for differences in price levels between countries.[1]

For our data set the average value of coral reef recreation is 184 US$ per visit. The median value, however, is 17 US$ per visit, showing that the distribution of values is skewed with a long tail of high values. As expected, the mean and median values of coral reef associated recreation vary considerably by location, recreational activity, and valuation method used. Figure 2 presents the mean and median coral reef values for each region, recreational activity, and valuation method respectively. Coral reef recreation in the Caribbean is shown to have the highest mean value and the US has the lowest. Mean coral reef recreation values in Australia, Southeast Asia, and East Africa are broadly similar. Regarding recreational activities, we identify seven categories of activity that have been valued in the literature. These categories consist of four individual activities (diving, snorkelling, viewing, and fishing) and three combinations of these activities. Value observations for the combination of diving, snorkelling, and viewing activities have the highest mean value, followed by diving by itself, and then all recreational activities valued together. Snorkelling receives the lowest mean value per visit.

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[1] In many cases, value estimates were elicited from foreign tourists visiting a coral reef. In such cases it is not appropriate to make a PPP conversion based on the price level in the country in which the coral reef is located but rather based on the price level in the country from which the tourists originate. This information was not available and so PPP conversions were not made in these cases, i.e. we assume that all foreign tourists face the same price levels as in the US.

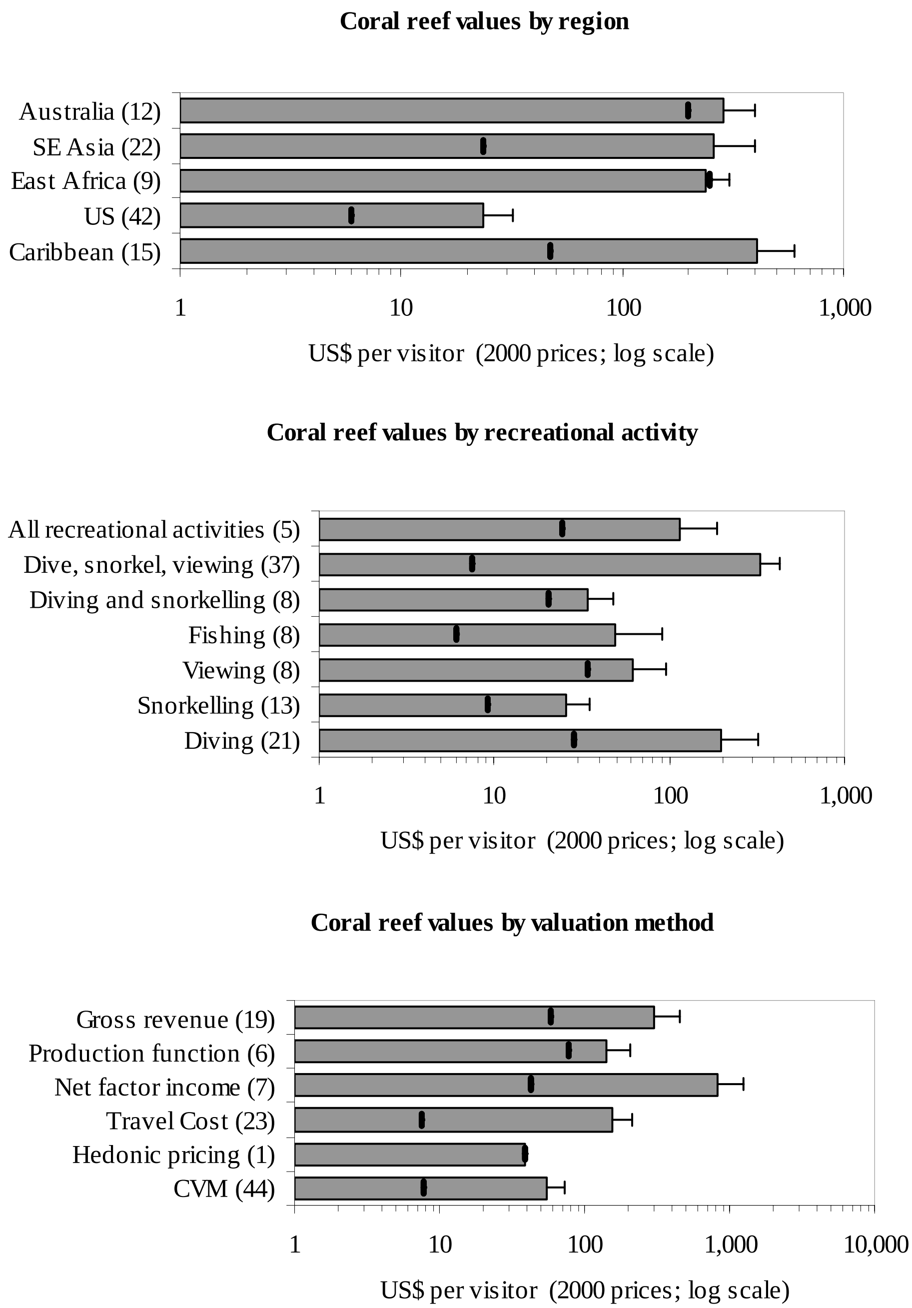

Figure 2. Coral reef recreation values by region, recreational activity, and valuation method. Values are presented on a log scale. The bars represent the mean value, the dots represent the median value and the error bars represent the standard error of the mean. The numbers in brackets are the number of observations for each category.

In terms of valuation methods, the *contingent valuation method (CVM)* has been the most widely used method for assessing coral reef recreational values. It must be noted that the valuation methods applied in the coral reef valuation literature differ considerably in terms of the welfare measures that they estimate (see Freeman 2003; Kopp and Smith 1993; Carson *et al.* 1996). This source of heterogeneity in the meta-data may lead to problems of non-comparability between estimated values and we need to be wary of comparing inconsistent concepts of economic value (Brouwer 2000; Smith and Pattanayak 2002). CVM is the only method capable of estimating non-use values and by directly asking respondents to state their WTP or WTA for (hypothetical) changes in environmental quality or quantity it provides estimates of the technically precise welfare measures of compensating and equivalent surplus. The *hedonic pricing* and *travel cost methods* estimate the Marshallian consumer surplus, which approximates, and is bounded by, the compensating variation and equivalent variation welfare measures. The *production function approach* estimates changes in consumer and producer surplus resulting from quantity or quality changes in an environmental good that is used as an input in a production process. If the price of output is unaffected by the environmental change (i.e., if demand for the good is perfectly elastic), only producer surplus is affected. The *net factor income approach* also estimates changes in producer surplus by subtracting the costs of other inputs in production from total revenue, and ascribes the remaining surplus as the value of the environmental input. The *total revenue approach* simply estimates values as the total revenue received from the sale of goods or services derived from the environmental resource in question. This approach ignores the cost of all other inputs in the production of these goods and services and will therefore tend to overestimate producer surplus. In our sample of value observations we find that the net factor income and gross revenue approaches tend to produce the highest estimates of recreational values. Aside from the hedonic pricing method, for which there is only one observation[2], the contingent valuation method produces the lowest value estimates.

Another coral reef characteristic that we may expect to determine recreational value is the area of dive sites available, which also indicates the area of coral cover present. Figure 3 plots recreational value by area of dive site and reveals a positive relationship between the two.[3] This suggests that recreationists have a preference for larger coral areas. Figure 3 also presents a plot of recreational value against the annual number of visitors to a site. This reveals a negative relationship, suggesting that coral reef recreationists prefer less crowded sites or the absence of other visitors. This graphical representation of the data helps to give an initial understanding of the determinants of variation in coral reef values found in the literature, although it does not account for the variation in values that is explained by variation in other important variables.

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[2] This single observation estimated using the hedonic pricing approach is from Cesar and van Beukering 2002, and estimates the amenity value of coral reefs on the Kona coast, Hawaii. We tested the sensitivity of the meta-regression results to the inclusion of this observation and found the results to be robust.

[3] The equation and R2 for the estimated least squares regression equation underlying the trendline is included in the Figure.

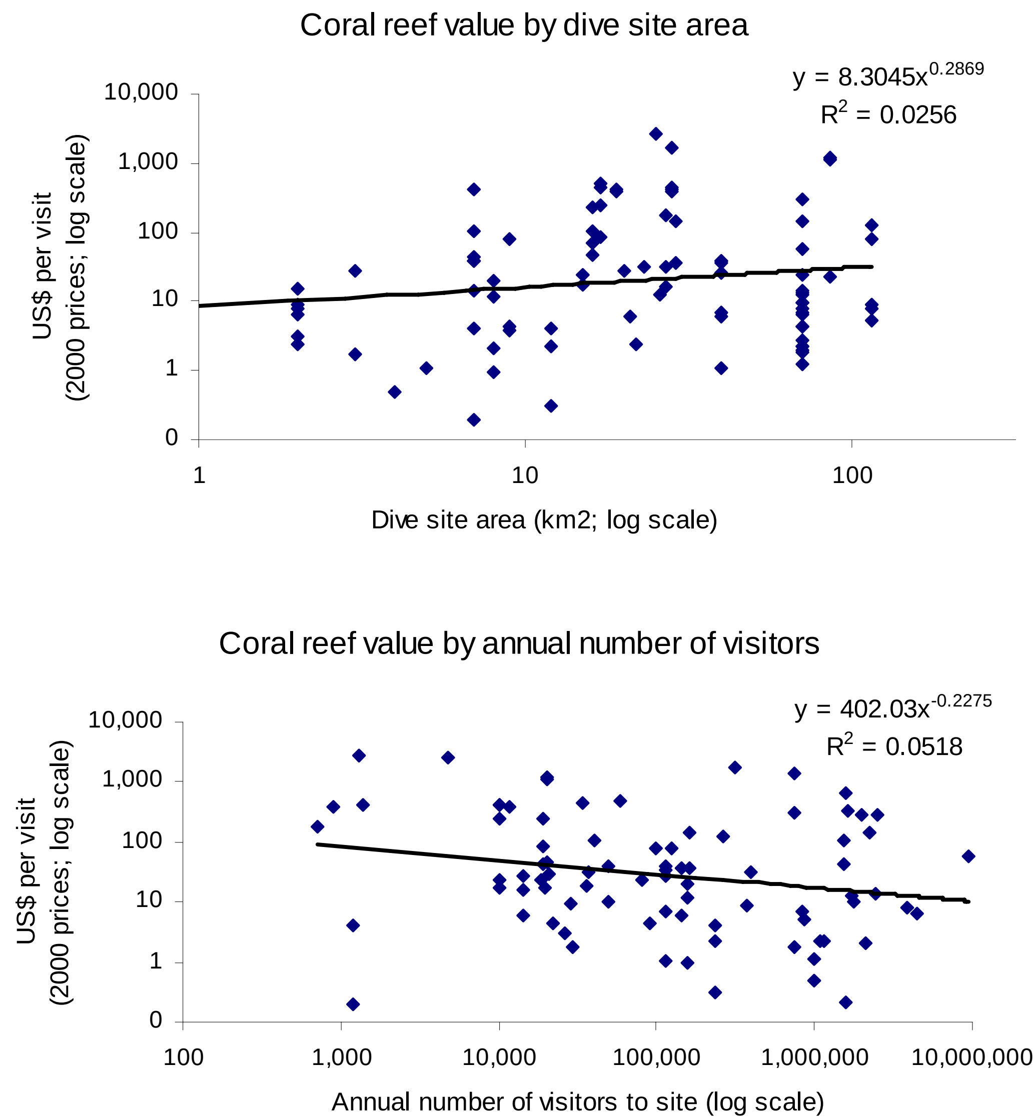

Figure 3. Coral reef recreational values by area of dive site and annual number of visitors to site.

4. Meta-regression results

The above exploratory analysis of the available data in the coral reef valuation literature does of course not allow for interactions between the various explanatory variables. In order to attain marginal effects – given the interference of potentially relevant intervening characteristics – we use meta-regression analysis to assess the relative importance of all potentially relevant factors simultaneously. The dependent variable in our regression equation is a vector of values in US$ per visit in 2000 prices, labelled *y*. The explanatory variables are grouped in three different matrices that include the study characteristics in *Xs* (i.e., valuation method), the recreational activity being valued in *Xa* (i.e. diving, snorkelling, fishing, etc.) the site characteristics in *Xc* (i.e., area of dive sites, number of visitors, and region). Due to missing data for some variables, the number of observations included in the meta-regression is reduced to 73. A list of the 52 studies from which these observations were taken is presented in Annex I. The model fit was considerably improved, and heteroskedasticity mitigated, by using the natural logarithms of the dependent variable, the number of visitors, and area of dive sites. Following Bateman and Jones (2003) and Brouwer *et al.* (1999), we use a multi-level modelling (MLM) approach to estimate the meta-regression.[4] MLM allows a relaxation of the common assumption of independent observations, and allows us to examine hierarchies within the data, such as similarity of estimates produced by the same author. The use of MLM provides an indication of where the assumption of independence may be invalid, and also improves the estimation of standard errors on parameter coefficients. The estimated model is:

$$y_{ij} = \alpha + \beta s X s_{ij} + \beta a X a_{ij} + \beta c X c_{ij} + u_j + e_{ij}$$

where the subscript i takes values from 1 to the number of observations and subscript j takes values from 1 to the number of authors. α is the constant term, u_j is a vector of residuals at the second (author) level, e_{ij} is a vector of residuals at the first (observation) level, and the vectors β contain the estimated coefficients on the respective explanatory variables. In this equation, both u_j and e_{ij} are random quantities with means equal to zero. We assume that these variables are uncorrelated and also that they follow a Normal distribution so that it is sufficient to estimate their variances, σ^2_u and σ^2_e respectively (Rasbash *et al.* 2003). This type of model is also known as a variance components model, given that the residual variance is partitioned into components corresponding to each level in the hierarchy. In our model, the level 2 residuals represent each author's departure from the population mean, represented by the constant term.

The results of the meta-regression are presented in Table 1 below. In this (largely) semi-log model, the coefficients measure the constant proportional or relative change in the dependent variable for a given absolute change in the value of the explanatory variable. For example, the coefficient of –0.82 for the dummy variable indicating that the recreational activity being valued is snorkelling means that, *ceteris paribus*, the value per visit will be 82% lower than when other recreational activities are valued.

Regarding the results on the regional indicators, East African reefs tend to provide significantly higher recreational values than reefs in other regions. Other regional dummy indicators included in earlier versions of the model were found to be insignificant and were subsequently dropped from the model.

The area of dive sites has a positive and significant coefficient, indicating that visitors prefer larger sites. It appears that reef recreationists are sensitive to the scope of the area they visit. This result is in line with earlier studies that find economic values of environmental and natural resources to be scope sensitive. These resources include visibility of national parks (Smith and Osborne 1996), habitat for the giant panda (Kontoleon and Swanson 2003), and health risk reductions (Bateman and Brouwer 2006). To our knowledge, scoping sensitivity has not been demonstrated for coral reefs before.

The number of visitors to a reef has a negative sign, suggesting that visitors prefer less crowded coral reefs. There is evidently some form of crowding-out effect with respect to the enjoyment of coral reef recreation. The first economic valuations of the impact of congestion in the recreational sector focussed at the willingness-to-pay by hikers to avoid encounters with others (Cicchetti and Smith 1973, 1976; Dekay and Smith 1978).

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4 The software used is MLwiN version 2.0 (see Rasbash *et al*. 2003).

Since then, the literature on congestion effects in terrestrial parks has grown substantially (Boxall *et al*. 2003). The impact of overcrowding in marine ecosystems, however, has not been explicitly studied yet.

Regarding the recreational activities being valued, there are few significant coefficients on the dummy variables indicating the recreational good. The only significant variable is for snorkelling, which receives lower valuations than other activities. This confirms the exploratory analysis in section 4.

Regarding valuation methods, the use of travel cost, production function, and net factor income approaches are all shown to produce significantly higher values than CVM. The contingent valuation method is represented by the constant term. This result is in contrast to the findings of Brander *et al*. (2006), which finds that wetland valuation studies using CVM tend to produce higher value estimates. If we consider CVM to produce a reasonably accurate estimate of a theoretically sound welfare measure, this result indicates an upward bias in the application of revenue and cost based approaches in the valuation of coral reef recreation.

Table 1. Meta-regression results.

Variable	Variable definition	Coefficient	Standard error
Constant		2.567**	1.124
Dive site area	Natural log of dive site area in km^2	0.956***	0.217
Number of visitors	Natural log of number of visitors	-0.225**	0.086
Snorkelling	Dummy: 1 = snorkelling; 0 = other service	-0.820***	0.298
East Africa	Dummy: 1 = East Africa; 0 = other region	1.457*	0.773
Travel cost	Dummy: 1 = Travel cost 0 = other method	1.831***	0.481
Production function	Dummy: 1 = Production function 0 = other method	3.357***	0.668
Net factor income	Dummy: 1 = NFI 0 = other method	1.778**	0.784
Gross revenue	Dummy: 1 = Gross revenue 0 = other method	0.610	0.419
Level 1 (estimate) variance		0.824***	0.175
Level 2 (author) variance		1.545***	0.559
N		73	
-2*loglikelihood		232.252	

*Significance is indicated with ***, **, and * for the 1, 5, and 10 percent level, respectively.*

Alternative specifications of this model were estimated with additional explanatory variables, including GDP per capita of the country where the reefs are located and population density for a 50 km radius around each study site. The coefficients on these variables were not significant, which is not surprising given that most of the observations in our data set are for foreign rather than local tourists. Another additional variable that was included in the meta-regression is a biodiversity index for each site. This index is defined as a composite measure of coral diversity and reef fish diversity. This variable also proved to be insignificant in explaining variation in coral recreation values, suggesting that recreationists are not sensitive to differences in biodiversity. We also re-estimated our model excluding the seven highest outlying values (those over 1000 USD per visit). The meta-regression results proved to be robust, with no significant change in the estimated coefficients.

We examine the influence of authorship effects on estimated values using a likelihood ratio test, for which the null hypothesis is that $\sigma^2_u = 0$. We compare the above estimated model with a model where σ^2_u is constrained to equal zero, i.e. a single level model. The value of the likelihood ratio statistic is 250.974 – 232.252 = 18.722. Comparing this to a chi-squared distribution on 1 degree of freedom, we conclude that there are real differences between the mean value estimates produced by different authors. In other words, value estimates from a particular author tend to be more similar than estimates drawn from different authors. Calculating the variance partition coefficient (1.545/1.545+0.824 = 0.653) shows that about 65% of total variance in coral reef recreational values can be attributed to differences between authors. This result contrasts with that of Bateman and Jones (2003), who find no evidence of authorship effects in their meta-analysis of woodland recreation values in the UK.

5. Value transfer

There is substantial academic and policy interest in the potential for, and validity of, value transfer as it offers a means of estimating monetary values for environmental resources without performing relatively time consuming and expensive primary valuation studies. There are two general approaches to value transfer: direct value transfer and function value transfer. The first involves simply transferring the value(s) estimated in one or more primary studies to the policy site in question. Ideally, the study site and policy site should be similar in their characteristics or adjustments should be made to the transferred value to reflect differences in site characteristics (Brouwer 2000).

The second approach involves transferring values to a policy site based on its known characteristics using a value transfer function, which can be an estimated benefit or demand function from a single study site or a meta-regression function derived from several study sites. Rosenberger and Phipps (2002) identify the important assumptions underlying the use of a value function for value transfer:

- There exists a valuation function that links the values of a resource with the characteristics of the relevant markets and sites across space and time, and from which values for specific characteristics can be inferred;
- Differences between sites can be captured through a price vector;
- Values are stable over time, or vary in a systematic way; and
- The sampled primary valuation studies provide “correct” estimates of resource value.

For a number of reasons value transfer may result in substantial ‘transfer errors’. One potential source of transfer error is that the characteristics of the site to which values are being transferred are not well represented in the data underlying the estimated value function (Brouwer 2000). A source of error that is specific to meta-analysis based value transfer results from the common limitation of valuation meta-analyses to capture differences in the quality and quantity of the services under consideration. It is often the case that the provision of goods and services are merely indicated with binary variables, and that quality is not captured at all. This limitation may translate into transfer errors, as the estimated transfer function cannot reflect important quality and quantity differences in characteristics across sites. A similar problem arises where non-identical services have been combined as one explanatory variable in the meta-analysis. Some level of aggregation across service types is often necessary in order to produce a manageable number of variables in the meta-regression, but at the cost of losing specific categories of services. Another source of error in transferring values from one site to another is that information on the availability of substitute sites at the study and policy sites is often omitted.

Given the potential errors in applying value transfer, it is useful to examine the scale of these errors in order to inform decisions related to the use of value transfer. In making decisions based on transferred values or in choosing between commissioning a value transfer application or a primary valuation study, policy makers need to know the potential errors involved. A prescribed acceptable level of transfer error is not meaningful as the level of error that is acceptable is likely to be context specific and related to other policy criteria (Jiang *et al*., 2004). One problem in assessing transfer errors is that this requires a comparison between transferred values and primary valuation estimates, which are subject to inaccuracies and methodological flaws of their own. In general, primary values are treated as 'true' value observations and transferred values as approximations, whereas they are in fact both approximations.

It is generally accepted that function transfers perform better than direct value transfers (Kirkhoff *et al*., 1997; Smith and Huang, 1995). This is because the use of benefit functions allows explanatory variables to be adjusted to represent the policy site in question (Bateman and Jones 2003). Meta-analysis based transfer functions have the added advantage of including information from a larger number of studies and sites. In addition, meta-analysis allows methodological differences between primary valuation studies to be controlled for. Rosenberger and Phipps (2002) review a number of studies that test the relative performance of direct value transfer and function value transfer (see for example Loomis 1992; Parsons and Kealy 1994; Brouwer and Spaninks 1999). The general conclusion is that function value transfer perform better than other approaches. Engel (2002) specifically compares the performance of benefit function transfers and meta-analysis based function transfers. The results of this comparison are mixed but the conclusions produce an encouraging view of meta-analysis based transfers.

To examine the prospects for, and accuracy of, value transfer to coral reef sites based on our meta-regression of recreational values, we employ an *n*-1 (or jack-knife) data splitting technique to produce 73 separate value transfer functions. Each function is then used to predict the value of the omitted observation in that case. The results of the value transfer exercise are presented in Figure 4. The smoothly upward sloping line represents the observed coral reef values in ascending order. The jagged line shows the values predicted using meta-regression based value transfer functions. It is clear that in some cases there is a considerable difference between the observed and predicted values. It is also apparent that the value transfer tends to over-estimate low observed values and under-estimate high values. As an indicator of transfer error we calculate the Mean Absolute Percentage Error (MAPE), which is defined as $(y_{obs} – y_{pred}) / y_{obs}$. The average and median transfer errors for our whole sample are 186% and 79%, which is high in comparison to other value transfer exercises (reviewed in Brouwer 2000; Rosenberger and Phipps 2002).

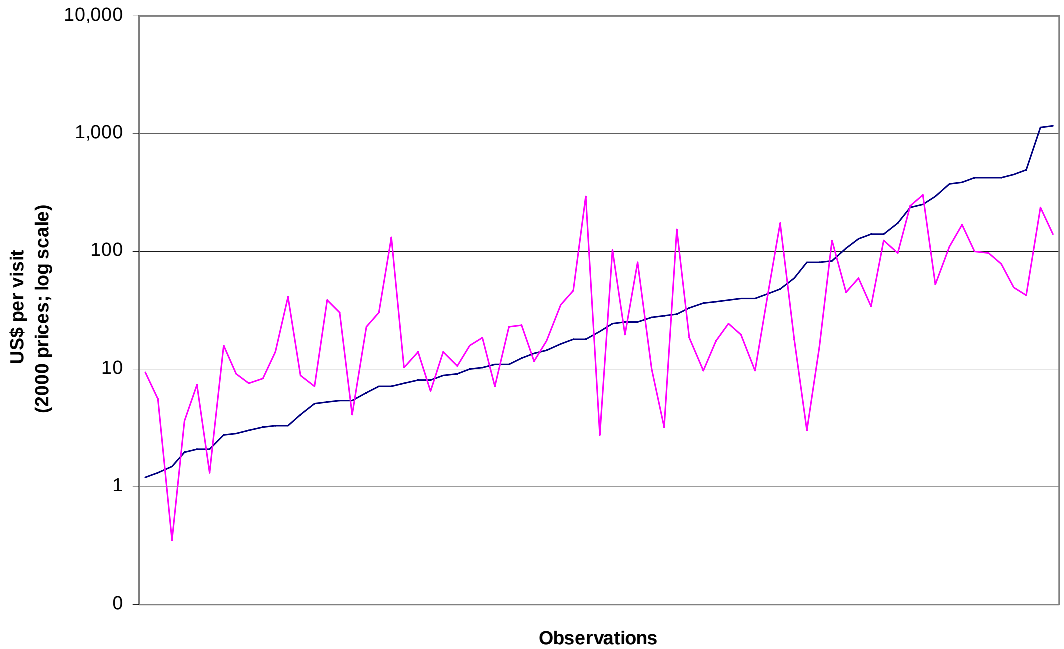

Figure 4. Observed and predicted coral reef recreational values.

Although the acceptable level of transfer error is context specific, these levels are unlikely to be acceptable in most policy-making scenarios. Based on the results of this analysis it would be advisable not to rely on value transfer to estimate site-specific recreational values for coral reefs. Meta-analysis based value transfer might, however, be an acceptable method for estimating recreational coral reef values at a regional or global scale, as to some extent site-level transfer errors will be cancelled out.

6. Conclusions/Discussion

With an average of around 10 new reef-related valuation studies each year, the knowledge base on the economic importance of coral reefs around the world is growing rapidly. The nature of these studies varies widely both in terms of the methodology used and benefits addressed. Despite this large variation, general lessons can be learned from this wide array of information through the application of meta-analysis.

Two important results from this meta-analysis are that reef recreationists appear to prefer reefs with a larger area of dive sites and fewer fellow visitors, i.e. they are looking for an unfettered and uncrowded experience of the marine environment. This provides the first evidence of scope sensitivity and crowding out effects in marine recreation. These results may be useful from the perspective of reef management and the design of recreational access. Reef managers should realise that restricting the area of dive sites or increasing the number of permitted visitors will reduce the attractiveness of that reef area.

An important lesson from this study relates to the manner in which economic valuation studies on coral reefs report their results. Many of the valuation studies collected for this meta-analysis lack fundamental information, such as the characteristics of the coral reef studied (e.g. area, quality, location), and the specifics of the methods used (e.g. sample size, number of non-respondents). This inadequate reporting is reflected in the fact that we collected 166 studies but only 52 of these yielded sufficient information for inclusion in a statistical meta-analysis. The scope for performing meta-analysis on coral reef valuation studies, and on the economic valuation literature in general, would certainly be improved if there were a standard protocol for the reporting of valuation results.

Based on the authors' experience of other meta-analyses of environmental values (e.g. Brander *et al.*, 2006; Brouwer and Brander, forthcoming), the quality of valuation studies for coral reefs seems to be lower. This is indicated by the fact that the majority of valuation studies on coral reefs are published as grey literature rather than in academic journals. Moreover, the result that authorship proved to be a significant explanatory variable in our meta-regression is also a sign that past coral reef valuation studies may not have followed an unbiased approach.

On a more promising note, several methodological developments can be observed in the field of coral reef valuation that may increase the quality of reef valuation in general. For example, spatial variation is increasingly taken into account by the application of Geographic Information Systems (GIS). Another example of novel application is the use of discrete choice experiments that better allows for the estimation of non-use values such as cultural attributes.

By focusing our meta-analysis on estimates of recreational values associated with coral reefs, we address a particular interest in coral reef valuation. A common motivation of many coral reef valuation studies is to determine the WTP of recreational users for conservation of the reefs they are visiting in order to set user fees for access. Given the high costs of performing valuation studies, there is considerable interest in using (meta-analysis based) value transfer to set user fees.

The results of our analysis on the accuracy of using estimated meta-regression functions for site-specific value transfer suggest that this is not (yet) a sufficiently accurate approach. Although meta-analysis based value transfer may be acceptable in some contexts, there is evidently still a need for high quality primary valuation studies of coral reefs.

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Annex I: List of studies included in the meta-regression and the number of observations taken from each.

Author	Year	N
Andersson	2003	4
Arin	1998	1
Ayob *et al*.	2000	1
Bappenas	1996	1
Berg *et al*.	1998	2
Bowker & Leeworthy	1998	1
Cesar & van Beukering	2004	4
Cesar & van Beukering	2002	7
Cesar *et al*.	2003	6
Davis *et al*.	1996	1
Dixon	1993	1
Dixon *et al*.	1993	1
English *et al*.	1996	1
Hodgson & Dixon	1988	1
Johns *et al*.	2001	12
Leeworthy & Wiley	1996	1
Leeworthy & Bowker	1997	1
Lindberg	1993	1
Mak & Moncur	1998	2
Ngazy	2004	2
Pendleton	1995	2
Pham & Tran	2001	3
Riopelle	1995	2
Seenprachawong	2003	3
Setiasih	2000	2
Sudara *et al*.	1991	2
Tabata & Reynolds	1995	1
Vogt	1997	1
Weber *et al*.	1996	1
White *et al*.	1997	1
White *et al*.	2000	1
Wright	1994	2
Yeo	2004	1

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